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- | | |
|-----|--------------------------------------------------------------------------------------------------------------------|
| . | not available for any reference period |
| .. | not available for a specific reference period |
| ... | not applicable |
| 0 | true zero or a value rounded to zero |
| 0* | value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded |
| P | preliminary |
| r | revised |
| x | suppressed to meet the confidentiality requirements of the <i>Statistics Act</i> |
| E | use with caution |
| F | too unreliable to be published |
| * | significantly different from reference category ($p < 0.05$) |

Longitudinal trajectories of sleep duration in the general population

by Heather Gilmour, Saverio Stranges, Mark Kaplan, David Feeny, Bentson McFarland, Nathalie Huguet and Julie Bernier

Abstract

Background

Sleep duration has been associated with overall health status, health behaviours, and mortality. Little is known about habitual longitudinal patterns of sleep in the general population. Furthermore, evidence about whether sleep duration has declined in recent years is contradictory.

Data and methods

The study was based on 8,673 adults aged 18 or older in 2002/2003 (cycle 5 of the National Population Health Survey) and used five self-reported biennial measurements of sleep duration spanning eight years. Multiple distinct trajectories of sleep duration were estimated using latent class growth modeling.

Results

Four modelled trajectories of sleep duration were identified: short (11.1% of the population), low-normal (49.4%), high-normal (37.0%), and long (2.4%). The short, low-normal and high-normal sleep trajectories each exhibited a slight linear decline in hours of sleep over the eight years of follow-up. Poor sleep was predictive of trajectory group membership and associated with a decrease in sleep duration for three of the four groups. Age and sex were also significant predictors of trajectory group membership.

Interpretation

Trajectory analysis is a useful descriptive tool in the investigation of sleep duration over time.

Keywords

Latent class growth modelling, longitudinal studies, PROC TRAJ, sleep deprivation

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Problems sleeping are relatively common—in 2002, for example, about 13% of Canadians aged 15 or older reported trouble falling or staying asleep.¹ In the future, sleep problems may become even more prevalent because of the growing share of elderly people in the population and increases in the prevalence of obesity and other physical and psychiatric co-morbidities associated with sleep disturbances.²⁻⁵

Sleep duration and sleep quality are closely related. Moreover, the extremes of sleep duration have been related to premature mortality^{6,7} and conditions such as diabetes, hypertension, heart disease, and psychiatric disorders.^{8,9}

A few studies of highly specific populations suggest the potential impact of changes in sleep duration on health outcomes.¹⁰⁻¹² But it is not clear that the relationship between short or long sleep and poor health is causal, or that altering sleep duration will result in improved health.¹³ Short or long sleep may be a risk marker rather than a causal factor for poorer health outcomes and the severity of co-morbidities.^{4,14} More generally, whether habitual hours of sleep have changed in recent years is unclear, with conflicting findings reported in the literature.¹⁵⁻¹⁷ Studies that identify population subgroups with differing longitudinal sleep patterns are needed to investigate these questions.

This is the first population-based analysis to use a group-based modelling approach to identify several distinct

trajectories of sleep duration in a large, nationally representative sample of Canadian adults. Five self-reported measurements of sleep duration from the National Population Health Survey (NPHS) spanning eight years were used. Sleep quality at each cycle was included in the model as a factor that may directly influence the course of sleep trajectories.¹⁸ The extent to which age and sex predict sleep duration and trajectory group membership was also examined. Because dealing with a small number of groups is less complicated than analyzing hundreds of individual trajectories,¹⁹ these modelled trajectory groups will aid the further analysis of longitudinal sleep data.

Methods

Data source

This study was based on a longitudinal sample from the five most recent cycles (2002/2003 through 2010/2011) of the biennial NPHS. The NPHS, a longitudinal survey conducted by Statistics Canada, collected information about

health status, health behaviours, and other health determinants from a representative sample of Canadians living in the 10 provinces. Residents of Indian Reserves, institutions, Canadian Forces bases, and some remote areas were excluded. Of 20,095 individuals selected for the longitudinal panel in 1994/1995, 17,276 agreed to participate—a response rate of 83.6%. Based on these 17,276 participants, the response rates for subsequent cycles were: 92.8% in 1996/1997; 88.3% in 1998/1999; 84.9% in 2000/2001; 80.8% in 2002/2003; 77.6% in 2004/2005; 77.2% in 2006/2007; 70.7% in 2008/2009; and 69.7% in 2010/2011. Detailed descriptions of the NPHS design, sample and interview procedures can be found in published reports^{20,21} and on the Statistics Canada website.

Data on sleep duration and quality are available from 2002/2003 (cycle 5) onwards; therefore, this analysis used cycles 5 to 9. An initial sample of 11,278 respondents were aged 18 or older at cycle 5; 2,226 were omitted from this analysis because three of five sleep observations were not available owing to death (621) or non-response (1,605); 64 were removed because they did not reply to baseline sleep questions. An additional 315 respondents had three or more sleep observations, but had died by cycle 8 or cycle 9. Potentially, those who died may have had illnesses that could affect their sleep patterns. However, they were excluded to avoid introducing bias by including some respondents who had died during the study period and not others. Thus, the final analytical sample comprised 8,673 adults (3,769 men and 4,904 women), representing 13.8 million individuals in 1994/1995. At baseline in 2002/2003, compared with respondents who remained in the analytical sample, those who were excluded because of non-response or death were more likely to be older (54.5 years versus 44.3 years, $p < 0.01$), men (51.2% versus 47.1%, $p < 0.01$), in the lowest income quintile (31.4% versus 16.2%, $p < 0.01$), and to report poor sleep quality (15.1% versus 11.7%, $p < 0.01$); they were less likely to have postsecondary education (26.2%

versus 42.1%, $p < 0.01$), to be White (87.0% versus 91.4%, $p < 0.01$), and to report good, very good or excellent self-perceived health (75.5% versus 91.3%, $p < 0.01$). The two groups did not differ in mean sleep duration (6.8 hours).

Definitions

Respondents were asked, "How long do you usually spend sleeping each night?", and were instructed not to include time spent resting. Responses were recorded in hourly intervals (for example, 5 to fewer than 6 hours), and were assigned an hourly value at the lower end of the range (for example, 5 hours). Those reporting "fewer than 2 hours" were assigned a value of 1 hour; those reporting "12 or more hours" were assigned a value of 12 hours. Specific instructions were not provided for people working night shifts. However, an examination of respondents who identified a night shift as their usual work schedule revealed that baseline responses to the sleep duration question ranged from 3 to 11 hours, with only two missing responses. This suggests that night shift workers responded based on their usual hours of sleep, regardless of whether these hours were during the day or at night.

Respondents who reported trouble falling or staying asleep "all" or "most of the time" versus "some," "a little," or "none of the time" were considered to have poor sleep quality. Because sleep quality could change over time, it was included in the model as a time-varying covariate, and so was involved in deriving the trajectory groups.

Age (continuous) at baseline (2002/2003) and sex were included as risk factors in the model.

Method

It is unlikely that longitudinal sleep patterns are homogenous throughout the population. The number of different longitudinal sleep duration trajectories and their structure are unknown. Trajectories of sleep duration were examined using a latent class growth modelling (LCGM) approach, also called group-based trajectory modelling, with the SAS PROC

TRAJ program.²² LCGM is useful for identifying meaningful and distinct groups in longitudinal data.

LCGM identified subgroups with similar sleep duration trajectories, each having a specific intercept, slope and estimated percentage of the population belonging to the trajectory group. Trajectory groups were modelled rather than based on manual classification of respondents' sleep duration, and consequently, are not directly observable.

Estimation of sleep duration trajectories was accomplished using the censored normal model (CNORM), which is appropriate for continuous data.¹⁹ Trajectory models with two to six patterns and varied shapes (for example, intercept, linear, or quadratic slope) were compared. The optimal number of trajectories and shapes that best fit the data was selected on the basis of: maximization of the Bayesian information criteria (BIC); statistical significance of modelling terms (for example, intercept only, linear, quadratic, cubic); whether 95% confidence intervals overlapped; the percentage of the population in each trajectory group; and the limited published literature.^{2,4} SAS procedures developed by Jones and Nagin²³ were used to compare slopes and intercepts across trajectory groups and to calculate 95% confidence intervals.

The trajectory model was fitted using maximum likelihood methods that allow for incomplete data, and assumes that missing data were missing at random.¹⁹ To obtain reliable parameter estimates of trajectories, at least three measurement time-points are needed for each case.¹⁹ Therefore, analysis was restricted to respondents with three or more self-reported sleep durations over the five data collection periods, one of which had to be baseline collection (2002/2003). Standardized longitudinal sample weights were applied to the analytical sample so that it was representative of the 1994/1995 population.

Trajectory analysis assigns each individual a probability (0 to 1) of falling into each latent trajectory group based on their reported sleep duration values at each of the five collection points.

Respondents were assigned to the trajectory group to which they had the highest probability of belonging. Diagnostics of model accuracy (Table 1) were based on standard criteria¹⁹ and indicate a good fit of the model.

Average posterior probability of group membership is an approximation of internal reliability of each trajectory—values greater than 0.70 or 0.80 indicate that the trajectory encompasses individuals with similar patterns of change.

and discriminates between those with dissimilar patterns of change.¹⁹ Among respondents assigned to a given trajectory in this analysis, average posterior probabilities were well above the minimum desirable level of 0.70. The minimum probability of membership did not fall below 0.50 in three groups, and was only slightly lower (0.48) for the low-normal group. The odds of correct classification were also above 5.0 for each group.

Derived trajectories may vary significantly with the inclusion of time-varying covariates (in this case, sleep quality) and are not directly comparable with trajectories identified without adjusting for time-varying covariates.¹⁹ For this analysis, models with and without the inclusion of sleep quality as a time-varying covariate both yielded a four-group model with similar intercepts and shapes, but with slight differences in the percentage of the population assigned to each trajectory (data not shown). Longitudinal trajectories of sleep with the inclusion of sleep quality as a time-varying covariate were best characterized by a four-group model (Figure 1, Table 2).

Sample sizes in the four modelled trajectory groups were 873 for short sleep; 4,372 for low-normal sleep; 3,249 for high-normal sleep; and 179 for long sleep.

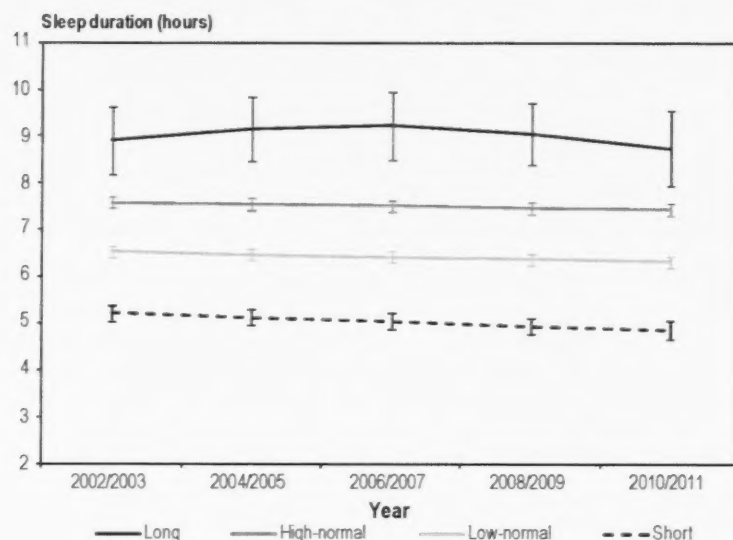
The Wald Test was used to determine whether coefficients differed significantly from one another.^{19,23}

Table 1
Diagnostics of sleep duration trajectory group assignment accuracy

Sleep duration trajectory group	% distribution	Posterior probability			Odds of correct classification
		Mean	Range		
			from	to	
High-normal	37.0	0.87	0.50	1.00	11.4
Short	11.1	0.89	0.50	1.00	64.8
Low-normal	49.4	0.85	0.48	1.00	5.8
Long	2.4	0.89	0.51	1.00	329.0

Source: 2002/2003 to 2010/2011 National Population Health Survey, longitudinal sample (square).

Figure 1
Sleep duration trajectories, household population aged 18 or older, Canada excluding territories, 2002/2003 to 2010/2011



I = 95% confidence interval

Note: Poor sleep quality was included in model as time-varying covariate, and therefore, was included in deriving trajectory groups.

Source: 2002/2003 to 2010/2011 National Population Health Survey, longitudinal sample (square).

Results

The majority of adults were classified in either the low-normal (49.4%) or high-normal (37.0%) sleep trajectory group (Table 1). Over the eight years, predicted average sleep duration decreased from 7.6 to 7.4 hours for the high-normal group, and from 6.5 to 6.3 hours for the low-normal group (Figure 1, Table 2). The short sleep trajectory represented 11.1% of the population and also followed a slight downward linear trend over time from 5.2 to 4.9 hours. The long sleep trajectory represented the smallest percentage of the population (2.4%), and followed a quadratic trend.

Based on the Wald test, the intercepts for each of the four trajectory groups differed significantly ($p < 0.01$) from each other. In addition, the linear terms of the short sleep group and the high-normal sleep group were significantly different ($p < 0.05$), indicating that the overall slopes of their trajectories were not parallel.

Poor sleep quality was associated with sleep duration over time. It was significantly related to a decrease in

sleep duration over the eight years in the short, low-normal and high-normal sleep groups ($p < 0.01$), but not in the long sleep group (Table 2). Coefficient estimates were significantly different ($p < 0.01$) from one another, indicating that the effects of poor sleep quality varied across trajectories.

Age and sex were included in the model as potential predictors of trajectory group membership. Male sex was a significant predictor of membership in the short and low-normal trajectory groups, compared with the high-normal group, but it did not predict membership in the long sleep group. Based on Wald tests of coefficient magnitudes, sex did not differentially predict membership in the short or low-normal groups. Increasing age was positively associated with membership in the short and long sleep groups, compared with the high-normal group, but negatively associated with membership in the low-normal sleep group. Significance tests of the magnitude of coefficient estimates indicated that age ($p < 0.01$) differentially predicted membership in specific trajectory groups.

In the baseline year, 2002/2003, the mean ages of the short and long sleep groups were 49.4 and 50.7 years, respectively, significantly older than the high-normal sleep group (44.4 years)

(Table 3). The mean age of the low-normal group was younger at 43.1 years. Men made up 51.7% of the low-normal group and 45.0% the short sleep group, significantly higher than the percentage of men in the high-normal sleep group (41.4%). Members of the short and low-normal sleep groups were more likely than those in the high-normal group to report poor sleep quality. The long sleep group did not differ significantly from the high-normal group with respect to the percentage of men and the prevalence of poor sleep quality.

Discussion

This study identified four distinct sleep duration trajectories. The majority of the adult population (86.4%) were classified in either the low-normal or high-normal group. Both groups maintained trajectories within the desirable range of 6 to 8 hours of sleep^{7,16} throughout the eight years.

Of particular relevance to public health is the percentage of the population at the extremes of sleep duration (short and long sleep groups), which have been associated with the risk of poor health.^{7,16} As reported in cross-sectional studies,^{4,24-27} long sleep was the least prevalent (2.4%), and 11.1% had a short sleep trajectory.

Sleep duration trajectories derived from longitudinal data are more informative than a single cross-sectional observation, since it is not possible to determine if that observation is indicative of a pattern over time or is likely to change in subsequent measurements. In fact, cross-sectional studies have reported percentages of the adult population sleeping 6 or fewer hours ranging from 7.5% to 37.2%, and percentages sleeping 9 or more hours ranging from 4.0% to 13.9%.^{4,24-26} In this analytical sample, the percentages reporting 6 or fewer hours and 9 or more hours of sleep at baseline (2002/2003) fell within these broad ranges: 36.1% and 5.0%, respectively. However, based on repeated measures, the habitual short and long sleep groups made up much smaller shares of the adult population: 11.1% and 2.4%, respectively. This suggests that the percentages of people in the extremes of sleep duration at a given time are likely to surpass the percentages who are habitual short or long sleepers over an extended period. Whether habitual short or long sleep patterns have different associations with health outcomes than does periodic sleep duration remains to be examined in further longitudinal studies with repeated sleep measures.

Table 2

Results of sleep duration trajectory model, including quality of sleep, age and sex, household population aged 18 or older, Canada excluding territories, 2002/2003 to 2010/2011

Parameters	High-normal sleepers		Short sleepers		Low-normal sleepers		Long sleepers	
	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error
Intercept	7.65	0.06**	5.57	0.09**	6.68	0.06**	8.34	0.30**
Linear	-0.04	0.01**	-0.08	0.02**	-0.04	0.01**	0.60	0.24*
Quadratic	-0.11	0.04**
Poor sleep quality	-0.35	0.06**	-1.18	0.09**	-0.89	0.05**	0.95	0.91
Time-stable co-variables (high-normal is reference group)								
Constant	reference group	...	-2.11	0.34**	0.32	0.19	-3.92	0.63**
Age	reference group	...	0.02	0.00**	-0.01	0.00*	0.02	0.01*
Male	reference group	...	0.26	0.11*	0.47	0.08**	0.17	0.30

... not applicable

* $p < 0.05$

** $p < 0.01$

Source: 2002/2003 to 2010/2011 National Population Health Survey, longitudinal sample (square).

Evidence of a decline in habitual hours of sleep in recent decades is not conclusive.^{15,16} The results of this study show a slight decrease over time for three of the trajectory groups, but it may not be large enough to be clinically relevant. Longer follow-up periods may be needed to detect meaningful changes in sleep duration.

The model did not identify any trajectory characterized by an overall increase in sleep duration or by a variable sleep pattern. While the data may include respondents with variations in hours of sleep, such patterns did not represent (a) distinct trajectory group(s).

Because the trajectory group classifications are probabilistic, each individual assigned to a given trajectory need not precisely follow that pattern of sleep duration. However, the model diagnostics were all strong, indicating that the modelled trajectory groups performed well in placing individuals with similar patterns of change in the same group and in discriminating between trajectories with dissimilar patterns of change.

Sleep quality was a significant predictor of sleep duration over time, and was differentially associated with trajectory group membership. This suggests that both sleep duration and quality should be considered in epidemiological studies of sleep patterns.

The association of short sleep with advancing age is consistent with previous reports of a higher prevalence of sleep disturbances and use of sedative hypnotics among older adults.^{2,28} Age-related changes in sleep may also be the consequence of chronic physical and

psychological co-morbidities, which are common in the elderly.³⁻⁶ Other studies suggest that the relationship between self-reported sleep duration and age may be U-shaped, with younger and older adults sleeping longer than middle-aged adults,^{29,30} although long sleep duration in the elderly is likely to represent an epiphenomenon of chronic comorbidities.⁴

Men tend to sleep fewer hours than women,²⁹⁻³¹ consistent with their higher representation in the short or low-normal trajectory groups. However, evidence suggests a greater prevalence of self-reported sleep problems in women despite their longer duration of sleep.^{5,32} These gender differences may be partially due to differential self-reporting of sleep habits.³³

Strengths and limitations

Strengths of this study include a large population sample and longitudinal data for both sleep duration and sleep quality. In addition, inclusion of sleep quality as a time-varying covariate (rather than assuming it to be constant over time) more fully reflects the association between changes in sleep quality and sleep duration.

Several limitations are noteworthy. First, the test-retest reliability of the single item on sleep duration, and the accuracy of self-reported sleep duration compared with objective measures, are uncertain and open the possibility of misclassification of true sleep patterns.³⁴ Results from the Sleep Heart Health Study for a sample of people aged 40 or older in the general population found that self-reports tend to overestimate

sleep duration.³⁵ However, if the degree of overestimation is stable, trends will be estimated accurately. Moreover, self-reported problems related to sleep quality may be less prone to misclassification than self-reported sleep duration.¹⁷

Second, the response categories for the question, "How long do you usually spend sleeping each night?" are hourly intervals, not precise numbers. For example, if the response category was

What is already known on this subject?

- Evidence indicates that sleep duration is associated with general health status, health behaviours and mortality.
- People sleeping fewer than 6 or more than 9 hours are at the greatest risk of negative health outcomes.
- Most information about the population prevalence of sleep duration is based on cross-sectional data.
- Whether sleep duration has declined in recent years is unclear.

What does this study add?

- Four sleep duration trajectories were identified in the Canadian adult population—short, low-normal, high-normal and long sleepers.
- The percentage of the population who are habitual short or long sleepers is lower than the percentages estimated to be in these sleep categories at any one point in time.
- A small, but statistically significant, downturn in sleep duration was evident in three of the four trajectory groups.
- Age, sex and poor sleep quality were significantly associated with sleep duration.

Table 3
Baseline characteristics (2002/2003), by sleep duration trajectory group, household population aged 18 or older, Canada excluding territories

Sleep duration trajectory group	Mean age (standard deviation)	% men	% poor sleep quality
High-normal [†]	44.4 (16.5)	41.4	8.5
Short	49.4 (15.7)**	45.0*	24.3**
Low-normal	43.1 (15.2)**	51.7**	11.6**
Long	50.7 (19.0)**	45.0	9.7

[†] reference group

* significantly different from reference group ($p < 0.05$)

** significantly different from reference group ($p < 0.01$)

Source: 2002/2003 to 2010/2011 National Population Health Survey, longitudinal sample (square)

"6 hours to fewer than 7 hours," sleep duration was coded as 6 hours. This could result in underestimation of predicted sleep duration at each time point. But given the tendency for self-report to overestimate hours of sleep, the misclassification of modelled trajectories may be minimal.

Third, sleep duration and sleep quality were reported to the NPHS once every two years; fluctuations in the intervening period would not be captured.

Fourth, non-random attrition of study participants could result in bias if, for example, those who died or ceased participation in the survey were more likely to have certain sleep problems or patterns. A comparison of people excluded

from the analytical sample with those who were retained showed differences at baseline in several socio-demographic and health characteristics and in the percentage reporting poor sleep quality, but not in average sleep duration. Thus, the potential impact of attrition on modelled sleep trajectories is not clear.

Concluding remarks

Sleep duration and quality have public health implications. Evidence indicates that sleep is likely to affect general health status and lifestyle behaviours, and to influence the risk of several chronic conditions including cardiovascular disease and diabetes, and of overall mortality.²

Trajectory analysis is a useful descriptive tool in the investigation of sleep duration over time. No previous nationally representative longitudinal studies have addressed trajectories of sleep patterns. This study provides an estimate of the population persistently in sleep categories that potentially put them at risk of poor health. Future research might consider risk factors beyond age and sex (for instance, medical or mental health factors), as well as health outcomes associated with trajectory groups. The interplay between sleep quality and sleep duration is also an important area to be explored further. ■

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